pork industry handbook

COOPERATIVE EXTENSION SERVICE • UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Pumping Liquid Manure from Swine Lagoons and Holding Ponds

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Manure management is an integral part of a modern swine production system. If manure is not handled in a sanitary method, diseases or other problems can occur, reducing overall production efficiency. Facilities with slurry or liquid storage require careful equipment design to adequately distribute the material to a terminal site. The terminal site is usually cropland.

Design Factors

Design factors which must be considered when planning a swine manure distribution system are:

- climate,
- soil type,
- crops and their nutrient requirements (based on soil fertility test and type of crop),
- volume of manure to be applied (wet volume and dry weight basis),
- quantity of manure to be applied (based on nutrient content),
- possible salt and nutrient imbalances,
- environmental and legal considerations of the application site.

Once these basic design factors have been considered and preliminary calculations have been completed, the system can be planned. System design consists of four steps:

- selecting the pumping plant,
- selecting a distribution system (sprinkler or surface application equipment),
- sizing the pumping plant and distribution system, and
- establishing a management system to optimize equipment, energy use, labor and nutrient recovery.

Pumping Plant Selection

Pumping consists of lifting and pushing a liquid through a transport pipe to the application site (Fig. 1). To select the proper pump, consider pump capacity (gal./min.), suction lift elevation, the elevation difference between the pump and the application site, friction loss in the transport lines, pump efficiency, required pressure, and the maximum horsepower that may be used on the power source.

Pumping capacity must be determined on a site-specific basis. Determine the maximum amount of manure to be applied by estimating manure production and volume of flush or wash water used. Another pump capacity selection factor is the method of distribution, either a big gun, a low-pressure gated-pipe distribution line, or a conventional sprinkler irrigation system.

Calculate the *total dynamic head* the pump must work against. The total dynamic head is calculated by adding the suction lift elevation to the discharge elevation from the pump to the highest point in the system, plus friction loss in the transport pipe, plus the pressure needed at the nozzle. Lift head and elevation head are site specific. Determine the friction loss and required nozzle pressure from friction loss tables and the sprinkler manufacturer, respectively.

All pumps have a maximum theoretical suction lift height of about 34 ft. However, a practical limit is 20 ft or less due to pump limitations (small pump and suction line leaks, friction loss, etc.). Many common pump problems occur with the suction side of the pump. Pumps with small leaks in the suction lift pipe or those in poor repair will not develop enough lift for satisfactory performance. Minimize the suction lift or use flooded suction where possible.

Pump speed has a direct effect on capacity, pressure head developed, cavitation, and frequency of repair. Many smaller pumps are designed to run at 3,450 rpm with direct

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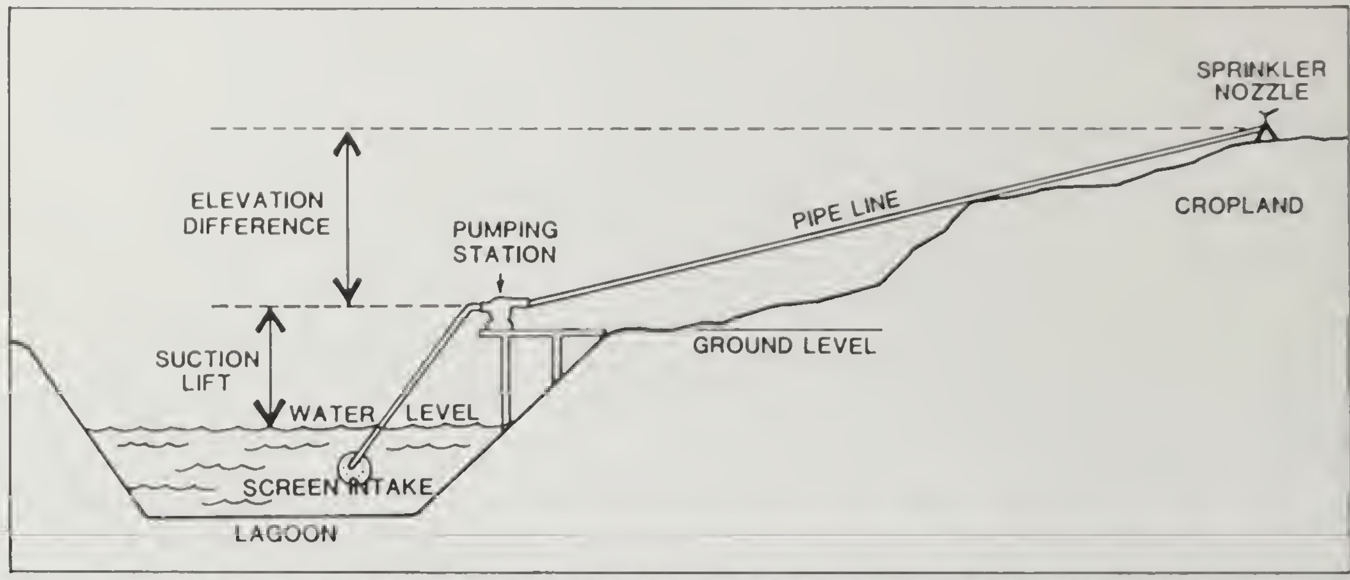


Figure 1. Typical pumping system. Pump selection depends on pump capacity required, suction lift, elevation difference, pipe friction loss and pressure required.

drive electric motors. Avoid these high speed pumps if they are to run continuously for long periods of time.

Refer to the manufacturer's pump curve when selecting a pump. It is often referred to as a *head-capacity curve*. The pump curve is a performance indicator for the pump under various operating conditions and must be studied carefully (Fig. 2). The capacity in gallons per minute (gpm) and the total dynamic head in feet are the horizontal and vertical axes, respectively. Pump curves should show the pump efficiencies, the brake hp, and frequently the net positive suction head for the pump. Unfortunately, the net positive suction head and pump efficiencies are not usually given for trash type or waste handling pumps (Fig. 2). The net positive suction head is very important to the operation of pumps. Failure to match the required and available net positive suction head is a major reason cavitation occurs. Cavitation is the formation of a partial vacuum within the liquid as it passes rapidly through the pump. When cavitation occurs, the pump sounds as if stones are passing through the pump chamber. Your pump dealer should be contacted to prevent cavitation and resulting problems.

The following example will illustrate use of a pump curve:

Example:

Determine the pump flow rate in gallons per minute (gpm) if the suction lift is 10 ft., the elevation difference is 25 ft. uphill, the pipe friction loss is 80 ft., and the discharge pressure is 30 psi.

Solution:

	(ft.)
Suction lift	10
Elevation head (Difference between highest discharge point and pump discharge)	25
Friction loss	80
Discharge pressure (calculate ft of discharge pressure by multiplying psi x 2.31)	69
Total dynamic head	184

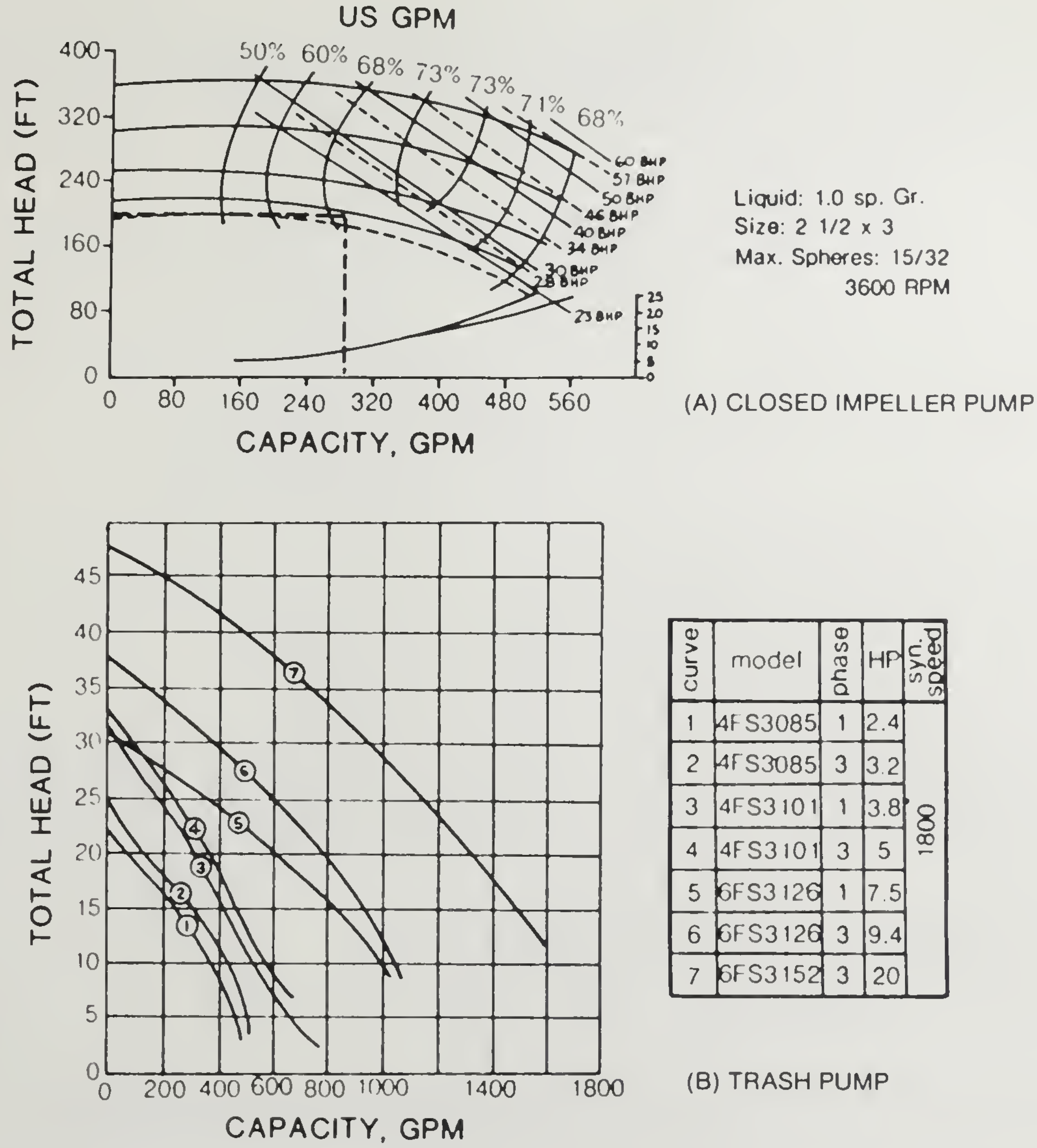
Answer (see Fig 2A) 290 gpm

Types of Pumps

Two types of pumps are available, centrifugal and positive displacement pumps. The volute type centrifugal pump is the most common for handling trash waters. Water enters the pump at the center and is carried by the impeller outward into an expanding spiral. The centrifugal pump permits control of flow rates by valving down the discharge side, however, this lowers the pumping plant's effective efficiency. Impeller design will ultimately determine the pump characteristics. Three types of impellers are available. They are closed, semi-open, and open A closed impeller pump develops high pressure but will not handle liquids with trash and other solids. Use it for irrigation with trash-free water, recirculating lagoon water, or pumping from a second stage lagoon directly onto cropland Semi-open and open impellers can handle liquids with solids A semi-open impeller has a plate on one side and is capable of handling liquids containing limited amounts of solids (less than 5%) and floating trash. The open impeller pumps have no plates attached to the impeller and can be used for high solids-content liquids with up to 15% total solids-content. A chopper blade is frequently attached at the inlet to break up large chunks and fibrous material before they enter the pump chamber Although open and semi-open impeller pumps move liquids with considerable solids content, the open impeller pumps will not develop sufficient pressure to operate a sprinkler irrigation system.

Positive displacement pump types include gear, helical screw, lobe, piston, and diaphragm pumps The first three pumps are characterized by a rotary motion to propel the liquid forward Capacity normally varies with the speed of the pump, however, a limiting factor is the thickness or total solids content of the liquid Thick, viscous fluids will not flow into the pump chamber rapidly enough to keep it at full capacity

The piston-type pump is normally placed lower than the manure to be pumped, and material is scraped into a hopper with a large throat opening Usually, check valves are placed near the inlet and outlet of the pump chamber to control the direction of material flow Diaphragm pumps consist of a pump casing with a flexible non-metallic dia-



curve	model	phase	HP	syn. speed
1	4FS3085	1	2.4	1800
2	4FS3085	3	3.2	
3	4FS3101	1	3.8	
4	4FS3101	3	5	
5	6FS3126	1	7.5	
6	6FS3126	3	9.4	
7	6FS3152	3	20	

Figure 2. Example of typical performance curve for a closed impeller pump (A) and trash-type pump (B).

phragm and check valves at the inlet and outlet of the chamber. As the diaphragm moves upward, the outlet check valve is closed and the intake or suction side opens allowing material to be drawn into the pump chamber. As the diaphragm moves down, the inlet check valve closes and material discharges from the chamber. Both the piston and diaphragm pumps are characterized by pulsating flows. The diaphragm pump has the ability to develop a suction lift of up to 10 ft. Pulsating pumps are not desirable for irrigation but are useful as transfer pumps for more viscous and highly fibrous materials.

Power required for operating pumps should be indicated on the pump curve. If the brake hp is unavailable, it can be calculated as follows:

$$\text{BHP} = \frac{\text{flow rate (gpm)} \times \text{total dynamic head (ft)} \times \text{specific gravity}}{\text{3,960} \times \text{pump efficiency (decimal equivalent)}}$$

The flow rate in gallons per minute can be obtained from your pump curve using the total dynamic head calculated for the particular site. For all practical purposes, specific gravity of manure can be assumed equal to one. The constant 3,960 converts the units into hp. Pump efficiency may be taken as 0.5 or 0.6 (50-60% efficient) if not given on the pump curve. Table 1 illustrates the hp rating required for various pumping capacities and pump pressures. This particular table does not account for the motor or power unit efficiency. Select the motor or power unit to deliver the required horsepower continuously by using the motor nameplate for electric motors, and the continuous duty rated horsepower for internal combustion engines. Keep in mind that electric motors are approximately 80% efficient. Water and/or air-cooled engines are 25-50% efficient.

Selecting the Distribution System

Several methods can be used to distribute liquid manure onto croplands. Sprinkler and surface application are broad

Table 1. Power requirements for selected pump capacities and heads.

Total dynamic head [1]		Pump capacity (gpm)					
		25	50	100	200	400	800
(psi)	(ft.)	Brake horsepower [2]					
20	46	0.6	1.2	2.3	4.6	9.3	18.5
40	92	1.2	2.4	4.6	9.2	18.6	37
60	139	1.8	3.5	7.0	14.0	28.0	56.2
80	185	2.3	4.7	9.3	18.6	37.4	74.7
100	231	2.9	5.8	11.7	23.3	46.7	93.3
200	462	5.8	11.7	23.3	46.7	93.3	187.7

[1] Total dynamic head = suction lift + elevation difference + pipe friction loss + nozzle pressure. Pressures (PSI) can be converted to ft. of head by multiplying pressure x 2.31.

[2] Assumes pump efficiency = 50%.

categories. Sprinkler application methods include large nozzle gun, towline, and center pivot. Surface application methods include gated pipe and surface flooding systems. Large nozzle (up to 2 in. diameter) systems are normally used for distributing liquid manure with a high total solids content and some debris. The nozzles will deliver up to 600 gpm on an area of 5 acres per set. Traveling systems may be pulled through the field or are self-propelled and may use smaller nozzles (Table 2) which cover more than 1 acre per run. The system can travel about a quarter of a mile on each run using flexible hoses to connect into the main line. Do not use water-turbine-driven traveling guns unless debris-free water is available.

Table 2. Capacities and coverage areas for irrigation nozzles.

Nozzle size	Nozzle pressure	Capacity [1]	Coverage Diameter	Coverage Area	Application rate
in.	psi	gpm	ft.	acre/set	in./hr./set
3/8	70	33	170	0.52	0.14
1/2	75	60	190	0.65	0.20
5/8	90	100	220	0.87	0.25
3/4	90	165	295	1.57	0.23
1	90	280	340	2.08	0.30
1 1/4	100	460	390	2.74	0.37

[1] To convert flow rate to in./hr. (1 nozzle only)

$$\text{Application rate (in./hr.)} = \frac{122.6 \times \text{flow rate (gpm)}}{\text{diameter (ft.)} \times \text{diameter (ft.)}}$$

Towlines are more adaptable on pastures where access to equipment is easy. A tractor must be used to move the system for each set. Towline systems have a lower power requirement than large nozzle guns because pressure requirements are less than 50 psi. Towlines usually are used for relatively debris-free water such as from a secondary lagoon or runoff holding pond. Screen the pump inlet with a screen having openings so anything drawn into the pump will pass through the pump and distribution system without clogging. Special or conventional center pivots can be used to distribute liquid manure. Special center pivot systems are currently available which have automatic shut-off valves on each tower. This allows use of larger nozzles (up to 1 in.) to distribute high total solids content water, conventional pumps, and the advantage of covering several acres per set. Alternate sprinkler heads are automatically opened as it rotates in its circle. One or more sprinkler heads may be operated depending on pumping capacity available. The conventional center pivot may be used, however, the water must be relatively free of debris to reduce plugging of the nozzles. In areas where cropland irrigation is normally used, holding pond or lagoon effluent may be blended with irrigation water. This practice has the benefit of the crop using nutrients throughout the growing season as well as supplying water.

Surface applications by gated pipe are common for conventional furrow irrigation. Care must be taken to avoid high total solids content materials when using gated pipe systems. Heavier particles will flow through the gate but will settle out within a very short distance causing irregular flow patterns. Flow through gates can be varied from less than 5 to over 40 gal./min. Slope of the land dictates the gate opening and thus the flow rate. Table 3 shows typical gate flow rates recommended for the various land slopes. Furrow irrigation is not recommended for slopes greater than 2% but has been used on land slopes up to 5%.

Table 3. Maximum recommended flow rates for gated pipe.

Land slope (%)	Flow rate (gpm/gate)
5	1
2	5
1	10
0.6	16
0.2	40

Surface flooding techniques may be accomplished by constructing a border or dike and flooding 3-6 in. of water on that area and allowing it to infiltrate. This system works quite well for smaller livestock operations because small pumping equipment or gravity can be used to empty lagoons or holding pond effluent onto a small area adjacent to the swine unit.

Sizing Distribution Lines

Sizing the distribution lines is the critical part of the design once selection of the system has been completed. Main lines and laterals must be large enough to reduce friction loss, yet maintain a flow velocity of 1 ft./sec. to maintain solids suspension. Avoid water hammer by maintaining flow velocity less than 6 ft./sec. Water hammer can cause damage to joints and valves in the system. Table 4 illustrates friction losses anticipated in various size pipes at different flow rates. An important factor which must be considered is the total solids content of the liquids to be distributed. When total solids content is greater than 5%, the liquid becomes viscous, adding to the friction loss. Table 5 illustrates some of the total solids contents which might be expected from various liquid manure storage systems. Therefore, it is recommended that sprinkler and/or surface application techniques use dilution water to maintain the total solids content below 5%. Table 6 shows dilution factors necessary to reduce the total solids content to 5% or less.

Table 4. Estimated friction loss for liquid manure in plastic pipe.

Inside pipe diameter	Pipe flow rate (gpm) 25	50	100	200	400	800
in.	Friction loss (ft.)/100 ft. of pipe [1]					
1	43.2				Not recommended	
1.5	6.0	21.8	77.4			
2.0	1.4	5.2	18.9	57.0		
3.0			2.6	9.6	35.0	
4.0		Not economical		2.3	8.4	40.0
6.0					1.1	4.1

[1] Assuming total solids content is less than 5%

Table 5. Approximate total solids content of swine manure in selected storage systems.

Storage system	Consistency	Total solids content [1]	Pump type recommended
		%	
Anaerobic storage	thick, viscous	8-12	piston, helical screw, diaphragm
Holding pond			
runoff	water	<1	closed impeller
manure	viscous	3-6	open or semi-open
Lagoon			
stage 1	turbid	1-3	closed to semi-open impeller
stage 2	water	<1	closed impeller

[1] Moisture content (%) = 100 - total solids content (%)

Table 6. Dilution rates to reduce total solids (T.S.) content of manure slurries.

Slurry T.S. content	Desired total solids content (%) 1	3	5
%	Dilution rates (gal. water/gal. slurry)		
15	14	4	2
12	11	3	1.4
10	9	2.3	1
8	7	1.7	0.6
5	4	0.7	-
3	2	-	-

Summary

The example problem (see page 6) illustrates the use of the tables and design factors necessary to plan and maintain a relatively problem-free system for distributing lagoon and holding pond effluent onto cropland

Salinity and nutrient imbalance

Because electrical conductivity (EC) is less than 4 (see laboratory analysis), salinity will not be a problem. Also, the county agent indicated all crops use K, Ca, and Mg. Na is not an essential element. However, with the warm, humid climate and low-salinity hydrologic soil group C, there should be no problem leaching the Na out. Nutrient imbalances will occur since phosphorus is applied at over 10 times that needed by the crops and potassium is applied at over 3 times that needed by the crops. Annual soil testing should be completed to avoid crop yield reductions due to nutrient imbalance or salt.

Environmental considerations

Because only 7.5 to 10.9 acres are necessary to dispose of the effluent, and the barn is located 5 miles north of the recreation area, no legal problem should exist if proper management is practiced.

Pump selection

The pasture is 15 acres with dimensions 1000 ft. long by 650 ft. wide. Therefore, a small traveling nozzle will be satisfactory. Table 2 indicates a 1/2-in. nozzle will deliver 60 gpm over 190-ft. diameter at 75 psi pressure, therefore:

Total dynamic head = suction lift (ft.) + elevation difference (ft.) + pressure head (ft.) + pipe friction head ft.

- suction lift (assumed) .... 10 ft.
- elevation difference (downhill from swine lagoon) .... -20 ft.
- pressure head (75 psi x 2.31 ft/psi) ...... 173 ft.
- friction loss
  Assume 1000 ft. of 2 in. pipe (Table 4)
  1000 ft. x 5.2 ft./100 ft. pipe = 52 ft.

Total dynamic head .... 215 ft.

The pump purchased must deliver 60 gpm against a total dynamic head of 215 ft. (93 PSI).

Brake horsepower

Table 1 indicates 5.8 hp will deliver 50 gpm against 215 ft. of head when the pump is 50% efficient—select a 6 hp motor.

Type of pump

Table 5 indicates a closed impeller pump will operate satisfactorily for lagoon effluent with total solids content less than 1%.

Management

The nozzle will travel 1000 ft. covering 190 ft. diameter or 4.4 acres per set (2 sets for corn, 3 sets for bromegrass).

Since phosphorus and potassium are applied at excessive rates, it is recommended that land be rotated every 4 or 5 yrs. to reduce the chance of yield reductions. Annual soil testing should be used for monitoring nutrient levels in the soil

Example problem

An anaerobic lagoon is used to treat flushed manure from a 500-head swine finishing barn The operation is located in southwest Missouri within 1 mi. of a stream which feeds into a recreation lake, located 5 mi south of the swine barn The owner has a center pivot 1/4 mi. north of the barn and has grass land south of the barn Approximately 5000 gal of flush water and manure are available per day

Solution

Climatological region (S W Missouri)	warm, humid
Soil type from county agent or Soil Conservation Service (SCS)	Group C soil (moderately heavy soil) low to medium salinity
Type of crop	
center pivot irrigated cropland	corn
not irrigated	pasture, brome
Nitrogen uptake (from county agent or SCS).	
corn (150 bu. corn/acre)	240 lb. nitrogen/acre-yr.
brome	165 lb. nitrogen/acre-yr.
Volume of lagoon water per year	
5000 gal./day x 365 days	1,825,000 gal./yr. (67 acre-in.)
Nutrients in lagoon effluent (from laboratory analysis)	
T.S. (dry matter content) = 0.3%	45,607 lb./yr.*
N = 4.0% d.b., 0.012% w.b.	1,824 lb./yr.**
P = 8.4% d.b., 0.025% w.b.	3,800 lb./yr.*
K = 11.9% d.b., 0.036% w.b.	5,473 lb./yr.*
Na = 1.7% d.b., 0.005% w.b.	760 lb./yr.*
Ca = 10.4% d.b., 0.03% w.b.	4,561 lb./yr*
Mg = 2.6% d.b., 0.008% w.b.	1.216 lb./yr*
E.C.	1.5 mmhos/cm
pH	8.1

Quantity of lagoon water to apply based on nitrogen needs

Quantity of nitrogen available in 1000 gal. lagoon water:

$$\text{lb. nitrogen} = 1000 \text{ gal.} \times 8.3 \text{ lb./gal.} \times \frac{0.012\%}{100} = 0.996 \text{ lb. nitrogen/1000 gal.}$$

Quantity of lagoon water to supply 240 lb. nitrogen/acre for corn

gal. lagoon water = 240 lb. nitrogen/acre ÷ 0.996 lb. nitrogen/1000 gal. = 241,000 gals./acre
= 241,000 gal./acre ÷ 27,152 gal./acre-in. = 8.9 acre-in./acre

Quantity of lagoon water to supply 165 lb. nitrogen/acre for bromegrass

gal. lagoon water = 165 lb. nitrogen/acre ÷ 0.996 lb. nitrogen/1000 gal. = 167,000 gal./acre
= 167,000 gal./acre ÷ 27,152 gal./acre-in. = 6.2 acre-in./acre

Land area required

Corn 1,825,000 gal. available ÷ 241,000 gal./acre = 7.6 acre, or
Bromegrass 1,825,000 gal. available ÷ 167,000 gal./acre = 10.9 acre

* Sample calculation: 1,825,000 gal./yr. x 8.3 lb./gal x 0.3 ÷ 100 = 45,607 lb./yr

**The form of N is important. Mineralized N is available to crops. Organic N must be mineralized by soil bacteria before it is available for crop use. If ammonia-N is high, much of this form of N may be lost to the air unless incorporated into the soil

Related Publications

- PIH-25 Fertilizer Value of Swine Manure
- PIH-35 Legal Guidelines for Swine Waste Management
- PIH-62 Lagoon Systems for Swine Waste Treatment
- PIH-63 Flushing Systems for Swine Buildings
- PIH-67 Swine Waste Management Alternatives
- PIH-79 Environmental Sanitation and Management in Disease Prevention

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pork industry handbook

COOPERATIVE EXTENSION SERVICE • UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Selection for Feet and Leg Soundness

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The swine industry needs more sound, durable breeding animals capable of a high level of productivity in present day housing and facilities. Seedstock producers commonly consider unsoundness to be caused by some modern housing systems. However, in most cases modern housing rearing merely expresses those defects already present. A pig, sound on feet and legs and reared on pasture or dirt lot, may be a structurally unsound pig in some modern systems. Other factors that may affect structural soundness include genetics, level of production, sex, nutrition, disease, floor surface, equipment location, and space available for exercise. Boar test stations and on-farm testing facilities provide an excellent opportunity to visually detect sound and unsound pigs that are fed and managed similarly.

Selection for feet and leg soundness is a subjective, visual process that is a necessary part of a progressive pork production scheme. Improvement through selection is possible, since recent studies report soundness to be medium in heritability. Several factors affecting feet and leg soundness are discussed here.

Skeletal Structure

Feet and leg soundness problems may occur in front and rear legs in all ages and sex classes of pigs. Boars are generally evaluated to be the poorest in leg structure. Poor rear leg structure may prevent a boar from successfully staying mounted on a female during mating. Unsound front legs may limit a boar's desire to mount a female. Affected pigs assume a posture of flexion of the front legs at the knee (buck knees) and elbow. The rear legs may be partially flexed and carried under the body to maintain stability. Affected pigs are straight-legged on rear legs and gait is peggy, short-strided, and painful. These signs are common with young boars aged 5-8 months when moved to new premises.

Skeletal structures in Figures 1 and 2 were drawn, in part, as the result of radiologic examination of live pigs. Emphasis was placed on angles formed at (M) front legs and (N) rear legs.

Undesirable front and rear leg structure is indicated in Figure 1; whereas "desirable" bone conformation is illustrated in Figure 2. The rear leg structure in Figure 1 has a rump that is too steep and the tail setting is too low. The angle (N) is larger in Figure 1 than in Figure 2. The hip, stifle, and hock joints (E, F, and G, respectively) lock in a straightline position with each step or in the breeding-mounted (boar) position. Boars that are too straight in the rear legs will occasionally fall backwards (sit down on the ground) during breeding. The rear feet may exhibit excessive sole wear with subsequent swelling of the pads and lameness. UNDESIRABLE.

The spine (Figure 1) is arched very high; the angle (M) is greater than 90 degrees, which positions the shoulder blade bone more directly over the front leg bones. Additional pressure may be applied at the elbow joint (B) and at the knee joint (C). The front leg knee joints often buckle. The abnormally straight front leg posture in Figure 1 results in abrasive wear of the pads and toes as shown in Figure 3. UNDESIRABLE.

In Figure 2 skeletal side view, note the flatter top, more level rump, and higher tail setting. The front legs slope from the shoulder, as you view them from the side (resembling a curved sickle blade). The angle (M) allows the normal shock-absorbing effect at the elbow joint (B). The angle (N) in Figure 2 is smaller than in Figure 1, the rear leg joints are properly angled to allow the hip, stifle, and hock joints to absorb pressure equally. The pasterns (D) are sloping and long to provide a cushioning effect,

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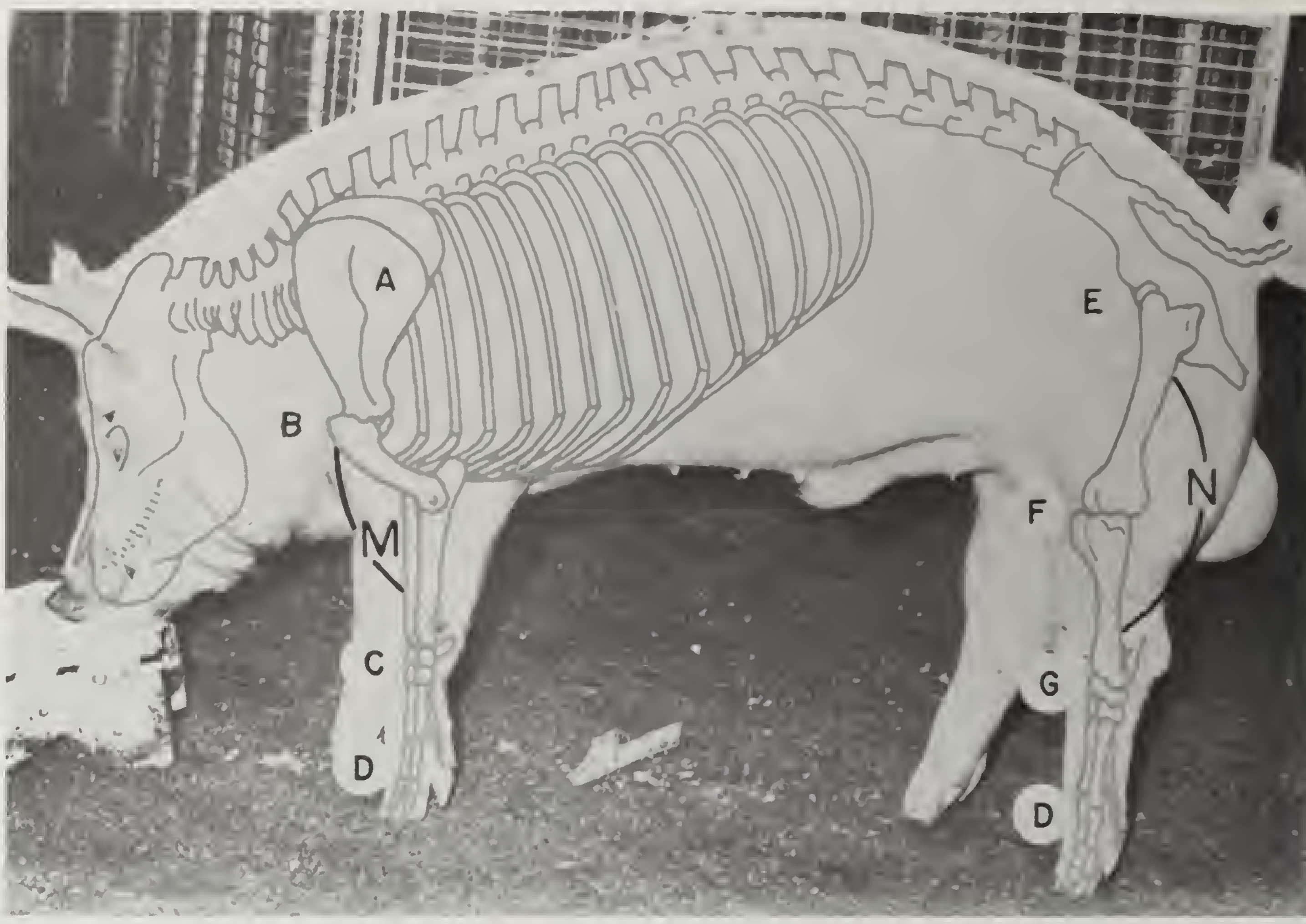

Figure 1. Undesirable front and rear leg structure.

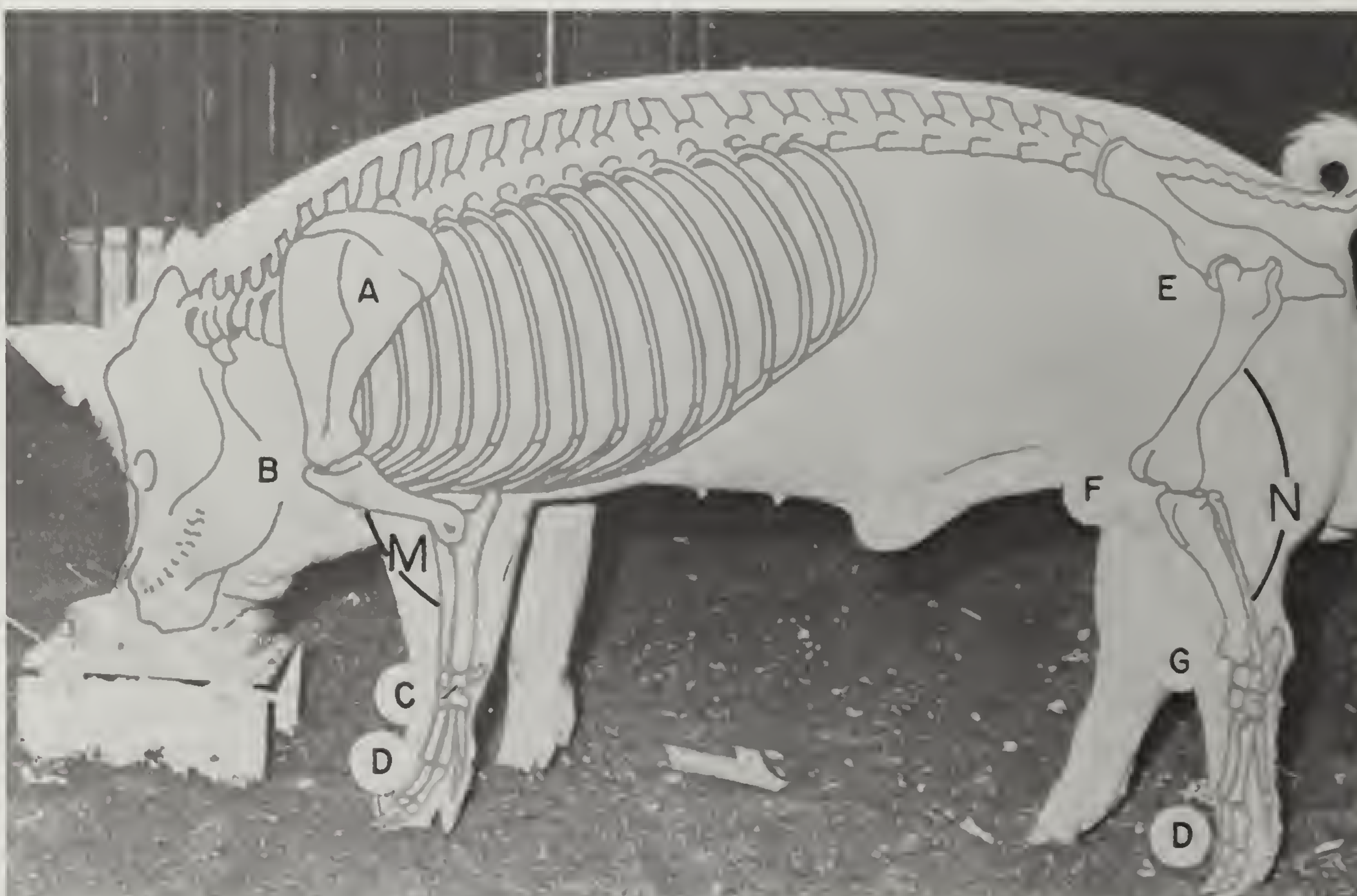

Figure 2. Desirable front and rear leg structure.

Figure 3. Abrasive wear of the pads and toes resulting from abnormally straight front leg posture.

and toes rest squarely on the floor surface. DESIRABLE.

In addition to structural differences noted in Figures 1 and 2, several other characteristics have to be considered in a soundness selection program.

1. Muscle—Extremes of muscle development that impair free movement or cause abnormal stance should be avoided. The desired muscling as viewed through the ham should be long and thick to facilitate free movement and desirable stance of feet and legs.

2. Skeletal Size—Extremely tall, flat, deep-sided breeding hogs have difficulty surviving on a solid concrete floor. Many boars (not all) described as extreme in their leg length and skeletal height have difficulty rising from concrete floors day after day. The process of getting up would normally include folding the legs to the underside of the body, rolling over to the belly, and then rising. Some tall, flat, deep-sided boars show an inability to easily fold the legs under their body and roll onto the belly. They will lie and flail with their legs until they contact something that will allow them to roll onto the belly, which increases the possibility of injury to already stiffened legs. Current standards would include visual selection for moderate length of leg combined with appropriate body length in both boars and gilts. Extremes in leg length are to be avoided.

3. Mobility—This is the ability to rise easily from the concrete and move freely with a long, easy stride. Lack of mobility can contribute to the presence of concrete blisters, calluses, or abrasions on leg joints. Note the open sore abrasion and concrete calluses (Figure 4) on the legs of an unsound sow.

4. Toe Size—The most common defect is small inside toes (Figure 5). As a pig gets older and heavier, leg conformation tends to conform to the shape and size of the toes. The ideal foot should include two even-sized toes, the toes should be big and slightly spread to improve ease of movement and stability. The outside toe is normally slightly wider and longer than the inside toe. Breeding age pigs with toe lengths on the same foot exceeding 1/2 in. difference are unacceptable (or should be

Figure 4. Abrasion on the leg of an unsound sow.

Figure 5. A pig with a common defect—small inside toes.

discriminated against) Figure 6 illustrates several desirable major feet and leg characteristics as follows 1)note the even-sized toes (T) on the foot with moderate spacings between the toes, b) analyze the excellent slope and cushion to the pastern (P) in the leg on the right, subsequently, the sole (0) of the hoof rests squarely on the concrete floor surface These rear feet and legs belong to a mature boar maintained and used for breeding on concrete for two years

5. Nutrition—The most emphasis, nutritionally, has centered on calcium and phosphorus mineral levels in rations. Pig growth rate appears to maximize at a lower dietary mineral intake than does bone mineralization followed lastly by bone breaking strength. Low dietary intakes of calcium and phosphorus will result in poor performance and bone tissue that is osteoporotic (low mineralization), bending when weight is placed on it. Structural soundness is affected Soft tissue and/or muscle formation continues at the expense of bone mineralization. Dietary levels of calcium and phosphorus over recommended National Research Council (NRC) requirements have been shown to increase breaking strengths of certain long bones with an increase in mineral content of bones. A positive relationship between increased (above NRC) levels of calcium and phosphorus in the diet and improved soundness has not been established. Calcium and phosphorus requirements of the young, growing boar are higher than those of gilts and barrows because of their more rapid growth rate, increased skeletal size, and improved feed efficiencies The National Swine Improvement Federation recommends dietary levels of .90% and .70% for calcium and phosphorus, respectively, for young, growing boars

Vitamin deficiencies rarely cause a structural soundness problem in the pig. However, a vitamin D deficiency results in a disturbance of calcium-phosphorus absorption and metabolism, causing a reduction in calcification of bones. A vitamin (B-group) called biotin has been suggested as a nutrient that will decrease foot problems In experimentally induced biotin deficiency and from field reports, the hoof horn becomes soft and rubbery and much more susceptible to damage if pigs are kept on rough and abrasive floors. Cracks and ulcers appear on the bearing surface of the foot (Figure 7) Abrasive floor surfaces alone can cause lesions very similar in appearance to those described for a biotin deficiency These lesions can be invaded by bacteria which produce infections in the foot and hock and result in lameness. Normal swine rations, supplemented with vitamins and minerals as recommended in Pork Industry Handbook fact sheets 2 and 52 should be adequate to maintain structural soundness

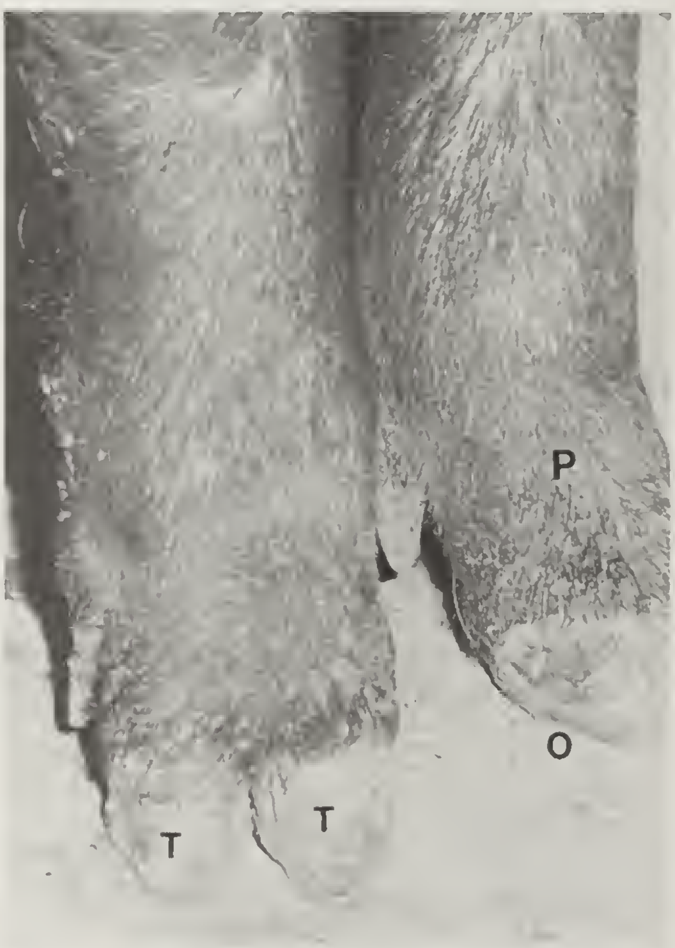

Figure 6. Desirable feet and leg characteristics. Even-sized toes (T); excellent slope and cushion to the pastern (P); a sole (O) of the hoof that rests squarely on the concrete floor surface.

Figure 7. Cracks and ulcers on the bearing surface of the foot.

6. Bone Abnormalities—Several bone disorders cause serious structural soundness problems These disorders include rickets, osteomalacia, and osteoporosis (lack of bone). Rickets (growing animals) and osteomalacia (mature animals) are caused by vitamin D deficiency and/or a deficiency or imbalance in calcium and phosphorus These bone disorders are not a serious problem where well-balanced diets are used

In many studies where unsound pigs have been dissected to determine a cause for improper flexion of joints and abnormal movement, osteochondrosis (OC) and osteochondrosis dissecans (OCD) conditions and lesions have been found. Unfortunately, in just as many studies, pigs classified as sound have, upon dissection, displayed just as many OC and OCD lesions. For this reason, the presence of OC and OCD alone cannot be the primary causes for bucked forward knees and uneasy movement. OC and OCD may, however, play a role in the total syndrome of leg unsoundness.

Osteochondrosis (OC) is an abnormality of bone and cartilage that occurs in young animals whose bones are growing rapidly. There is degeneration of bone and cartilage at the places where bones grow (the growth plate) and also the cartilage and underlying bone that form joints (especially larger joints with free range of movement such as the elbow and stifle). It should be noted that there is no inflammation associated with OC. OC is a generalized condition occurring in many locations of growth in the body including those of the limbs, vertebral column, ribs, etc. It is characterized by increased thickness of joint cartilage and widening or distortion and sometimes premature closing of the growth plate. The changes are due to inadequate blood supply resulting from blood vessel damage (often traumatic) rather than excessive cartilage growth. The condition may undergo satisfactory repair or it may persist and progress to severely crippling degenerative arthritis (osteoarthritis). If joint cartilage separates from the bone the condition is referred to as osteochondrosis dissecans. In severe cases the cartilage may become free floating inside the joint. In many cases, the whole cycle of separation, necrosis, and regeneration may occur without any defect in the joint cartilage.

In studies involving large numbers of pigs, 80 to 90% of all the pigs have evidence of some type of OC or OCD lesion. Fast-growing animals and boars do have a greater incidence of OC and OCD. OC and OCD are moderate to high in their heritability and have little or no genetic correlation to visual scores of unsoundness.

7. Bone Size—Larger bone size is reputed to be important for durability. Larger bone should be preferred, but not at the expense of structural correctness.

8. Floor Surface—Raising pigs on concrete has increased the number of lameness problems. Type of flooring within housing facilities has affected feet and leg soundness. Pigs grown on total slats have more problems than those on partial slats. Wider slats with rounded edges produce fewer problems than narrower slats with sharp edges. Aluminum and some other bare metal slats produce more lameness problems than plastic, concrete, or coated metal slats. The prevalence of footpad lesions increases on rough as compared to smooth concrete. Extremely smooth, wet concrete flooring presents areas for potential injury to feet and legs due to slippage accidents.

9. Exercise (Pen Space)—Researchers have observed that exercise will increase muscle tone and coordination. In one study, nonexercised pigs were the least sound, and unsoundness increased with age. Space per pig and pen dimensions may indirectly affect the amount of exercise a pig obtains. A long, narrow pen (length:width of 2.5:1) affords more exercise opportunity and should be considered desirable for breeding boars.

10. Genetic Control of Structural Soundness—Recent research studies report several important results to consider as follows

   a. Feet and leg soundness is moderate in heritability, thus, selection for feet and leg soundness combined with selection for important economic traits will result in improved performance of a herd over time.

   b. Average daily gain is lowly but positively correlated with feet and leg soundness, so fast-growing pigs that will stay sound can be produced.

   c. The genetic correlation between backfat thickness and front feet and leg soundness is moderately positive, the genetic correlation of backfat thickness with rear feet and leg soundness scores is low but positive; the genetic correlation of loin eye area with front and rear feet and leg soundness scores is moderately negative. These findings indicate that fatter, less muscled pigs are more likely to be sound on their feet and legs than are leaner, meatier pigs. These unfavorable genetic correlations can cause problems in selecting for leaner and more sound pigs. However, progress can be made by careful and persistent selection practices including use of a selection index composed of average daily gain and backfat thickness, along with visual appraisal and scoring of tested pigs for feet and leg soundness, in selecting both boars and gilts for breeding purposes.

Guidelines for Herd Improvement in Feet and Leg Soundness

1. Seedstock producers should use a structure and movement scoring system to evaluate all breeding herd candidates at a standard age or weight in the selection process. (See suggested scoring system.)

2. Commercial producers should purchase sound breeding stock from producers with a soundness scoring-culling system and with facilities that are similar to their own.

3. When possible, study the soundness of the dam, sire, and littermate pigs of those candidates you wish to purchase.

4. Avoid the use of adverse environmental conditions, i.e., rough floors, inadequate pen space.

5. Feed nutritionally balanced diets.

6. Provide consistent management practices on a daily basis to all pigs.

7. Separate lame or injured pigs from the group and place them in a well-bedded pen. A veterinarian can provide diagnostic effort and can make medical recommendations which should be helpful. In animals of value, radiographs are very helpful in determining the nature and extent of an injury or lameness, thus providing a basis for making a reliable prognosis. Culling should be considered for crippling lameness that persists for more than 4 weeks.

8. Recognize that it may take several generations of selection to attain the goal of acceptable structural soundness in the herd. Structural soundness is just one trait that should be considered in the selection process. Thus, it may not be possible to select animals with the best soundness scores in all cases. Compromise is usually required in the selection process in order to improve the herd in overall merit.

Feet and Leg Soundness Scoring System

The scoring system suggested below is from 1 to 10 (10 is best). Emphasis in the scoring system should be on (a) mobility—5 pts., (b) structure—4 pts., (c) even toe size—1 pt. Scoring may be done separately on front and rear legs (10 pts. each) or combined for front and rear legs.

Scores (Boars and Gilts)

9-10 Indicates a boar or gilt is largely free of feet and leg soundness problems and can be successfully used in modern facilities.

7-8 Indicates minor structure, movement and/or even toe size problems, but animal should be able to perform satisfactorily under any management system or facilities.

4-6 Indicates moderate soundness problems that restrict use of animal to dirt or pasture lots.

1-3 Indicates severe soundness problems that are unacceptable under any management system or facility.

From a practical standpoint, potential breeding stock should be ranked using a performance index, and only animals with a soundness score of 7 or higher should be selected to improve the breeding herd.

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